ARTERIAL COMPLICATIONS OF THE THORACIC OUTLET SYNDROME

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M.Ch Vascular Surgery

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DECLARATION

I solemnly declare that this dissertation titled "Arterial complications of the thoracic outlet syndrome" was prepared by me in the Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Chennai under the guidance and supervision of Prof T. Vidyasagaran, Professor & Head of the Department, Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Chennai. This dissertation is submitted to The Tamil Nadu Dr. MGR Medical University, Chennai in partial fulfillment of the university requirements for the award of the degree of M.Ch. Vascular Surgery.

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CERTIFICATE

This is to certify that the dissertation titled "Arterial complications of the thoracic outlet syndrome" submitted by **Dr R. Chithra** appearing for **M.Ch (Vascular Surgery)** degree examination in August 2013, is a bonafide record of work done by her under my guidance and supervision in partial fulfillment of requirement of The Tamilnadu Dr M G R Medical University, Chennai. I forward this to The Tamilnadu Dr MGR Medical University, Chennai.

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Review of Literature

PART I – REVIEW OF LITERATURE

1.1. Introduction

Thoracic outlet syndrome (TOS) describes a spectrum of symptoms and signs related to the passage of key anatomical structures through a narrow aperture on their way to the distal upper extremity. TOS results from compression of the neurovascular bundle in thoracic outlet area and the three components of the bundle in the thoracic outlet area are the brachial plexus, subclavian vein, and subclavian artery (SCA). Thus, there are three types of TOS, depending on which structure is compressed: neurogenic (nTOS), venous (vTOS), and arterial (aTOS).

The commonest form of TOS is neurogenic type. The arterial TOS forms less than 1% of cases, but the morbidity and mortality is severe that warrants immediate attention and management. The common etiology for aTOS is the presence of bony abnormalities. Cervical rib is found in approximately 0.5% of the general population and it contributes to the compressive neurovascular symptoms of the thoracic outlet. The symptoms of aTOS are caused by emboli arising from subclavian artery pathology, like intimal damage, stenosis, poststenotic dilatation or aneurysm.

The commonest etiology is presence of cervical rib. Other causes include anomalous first rib, post-traumatic callous formation in the clavicle, bony prominence or tumours in the clavicle, and rarely congenital fibrous band. The syndrome is caused by the anatomical narrowing caused by the cervical rib or anomalous first rib eliminating the space under the subclavian artery. This external compression results in repeated trauma in the intima of subclavian

artery, resulting in subclavian stenosis, thrombosis, aneurysm formation with mural thrombus and distal embolisation.

The consequences of cervical rib do not appear to be widely understood. Whilst most cervical ribs cause little or no trouble, and, at the most, require shoulder raising exercises, some are the cause of serious arterial compression. Much confusion has existed in the understanding of the vascular manifestations of cervical rib, and this confusion has often led to incorrect treatment with serious consequences. In this regard it is particularly important for the surgeon to deal with the diseased artery at the same time as the cervical rib is excised. The importance of recognition of arterial compression, before surgery is undertaken, is stressed.

Arterial complications of thoracic outlet syndrome are unusual. However, they are potentially much more serious than the more common neurologic manifestations, and in some cases they may lead to loss of the limb. The presenting symptoms vary according to the SCA disease status. Symptoms are those of arterial ischemia and include extremity paresthesia, pain, pallor, coldness, digital ischemia, and weakness. Seldom are there neck or shoulder symptoms, but patients may present with arm claudication. On examination, patient may present with all stages of ischemia, either acute or chronic, depending on the stage of arterial occlusion. Decreased pulses at rest, distal colour changes, ischemic finger tips, features of distal emboli and sometimes, raynaud's phenomenon are some of the presenting signs. The need for early detection of lesions caused by emboli is extremely important to prevent the adverse vascular events.

The routine diagnostic tests include, neck radiograph, duplex scan, digital pressures and waveforms. Sometimes, arteriogram, arteriography, and computed tomographic angiogram may be necessary to delineate the extend of arterial involvement. Magnetic resonance

imaging may be necessary in few cases of absent bony abnormalities, to find out the presence of congenital band or soft tissue compression.

There is no role for medical or nonsurgical treatment; surgery is the only option in aTOS. Surgical treatment is indicated in all cases of vascular impairment (pallor, reduced pulses, cyanosis, Raynaud's phenomenon, limb claudication, pain at rest or ulcers), in addition to patients with uncontrolled pain and paresthesia. The surgical armamentarium contains scalenectomy with or without rib resection, transaxillary 1st rib resection, resection of any constraining band or soft tissue, in addition to the management of SCA disease such as embolectomy, thrombectomy, aneurysm resection and repair. Cervical rib excision or scalenotomy is sufficient to relieve the symptoms of TOS without excision of the first rib, in most of the cases, presented early. Those who are presenting late with distal ischemia, the subclavian artery often require reconstruction as well. The excision of the diseased lesion followed by reanastomosis is usually feasible. If not, a venous or synthetic graft should be interposed.

There are two surgical approaches for the cervical rib resection: supraclavicular and transaxillary approach. Studies have shown that success rates have been similar between both techniques, although the supraclavicular approach allows for a better visualization of the scalene muscle. In addition, when the scalene muscle has any abnormality that could be responsible for the syndrome, it is possible to incise it at this moment; on the other hand, using the transaxillary approach, such procedure would be performed at a different surgical time. Complications of the surgery include phrenic nerve injury, brachial plexes injury, subclavian vein injury, and pleural injury resulting in pneumothorax.

Only a few series with large numbers of cases have been previously reported, so that the surgical strategy remains controversial regarding the optimum mode of access, which bony

elements to excise, and the management of thromboembolic complications. In order to plan the surgical management more efficiently, accurate assessment of the full scope of arterial involvement is required. The aim of this article, which is based on a prospective study of early and late surgical results, is to evaluate the etiology, clinical presentation, and management and to define more precisely the indications for surgery and the surgical methods to adopt in aTOS.

1.2. HIGHLIGHTS OF THE HISTORY

1.2.1. First Clinical Description

Several early anatomists, most notably Galen described the presence of cervical ribs. In 1821, Sir Astley Cooper attributed a pulseless cold arm to compression of subclavian artery by cervical rib, at Guy's Hospital.[1] Twenty years later, Gruber published what is still considered the definitive classification of cervical ribs.

1.2.2. First Surgical Excision of a Cervical Rib

Coote in 1861diagnosed prominent supraclavicular pulsation due to an extra rib in a case of absent radial pulse and performed the first successful cervical rib resection. [2]

1.2.3. Early Treatment with Nonvascular Methods

In 1815, physical methods were used for symptomatic relief. [3, 4] As early as 1910, Murphy was performing excision of normal first ribs for what had become known as cervical rib

syndrome. Law's descriptions of ligamentous attachments to cervical rib, followed by Adson and Coffey's publications in 1927 on dividing the anterior scalene muscle, helped shift the focus off the cervical rib. The scalenus anticus syndrome, described in the late 1930s by both Naffziger and DeBakey, was treated for a time by scalenectomy. These non-vascular methods such as, scalenotomy,[5] excision of the thrombosed artery,[6] and dorsal sympathectomy[7] when tried, resulted in little improvement. [8]

1.2.4. Physiology of Subclavian Aneurysms

Halsted reviewed reports of 716 cervical rib cases and explained that cervical ribs cause subclavian artery aneurysms that subsequently thrombose.[9] Roach demonstrated that vibrations in the range of audible sound weakens arterial wall and cause post-stenotic dilatation and aneurysm.[10]

1.2.5. Modern Era of Direct Arterial Repair

The appearance of surgical methods, such as arterial thrombectomy[11] and arterial homograft replacement, changed the management of arterial TOS. As an adjunctive procedure dorsal sympathectomy was used. [12] In1956, Peet coined the term TOS and described a therapeutic exercise program. Two years later, Standeven and Rob encompassed all previous anatomical names into this term. In 1962 Clagett presented high thoracoplasty for first rib excision, in 1966 Roos described tranaxillary first rib resection and a year later, Gol went through infraclavicular approach.

1.2.6. Endovasular options

The concept of adjunctive endoscopic video demonstrated the benefits of magnifying the relative inaccessible anatomic surgical area, which ensures a greater measure of safety during the transaxillary approach. In addition, intraoperative endoscopic video during the

transaxillary approach offers direct visualization of the congenital anomalies of the scalenus muscles and their compression of vital structures, greatly enhancing the likelihood of preserving functional integrity of the nerve, artery, and vein.

The early reports of endovascular surgery in highly selected patients are encouraging.[13, 14] There are instances of stent fracture, collapse, thrombosis or re-stenosis, when the decompression of thoracic outlet was not considered with endovascular repair of subclavian artery.[15] The results with increased experience are encouraging, but the validity of this approach was not determined by long-term results. In the evolution of endoscopy, the robotic instrumentation is done during computer-enhanced instrumentation of endoscopic transaxillary first rib resection. [16]

1.3. ANATOMICAL CONSIDERATIONS

1.3.1. ANATOMY OF THORACIC OUTLET

The earliest basic science studies have appropriately been morphologic in nature since thoracic outlet compression is still fundamentally considered to be an anatomic problem. Consequently, throughout the history of its medical and surgical treatment, attempts were made to understand the underlying structural abnormalities.

Definitions may vary from author to author, but it is generally accepted that the thoracic outlet is the area from the edge of the first rib extending medially to the upper mediastinum and superiorly to the fifth cervical nerve. The clavicle and subclavius muscles can be pictured as forming a roof, while the superior surface of the first rib forms the floor. Machleder's description of the thoracic outlet as a triangle with its apex pointed toward the manubrium is

helpful in visualizing the three-dimensional orientation of the structures, as well as the dynamic changes that can lead to injury. [17] In this model, the clavicle and its underlying subclavius muscle and tendon form the superior limb, while the base is the first thoracic rib.

The point at which these two structures "overlap" medially can be pictured as the fulcrum of a pair of scissors that opens and closes as the arm moves, potentially causing compression of the thoracic outlet contents.

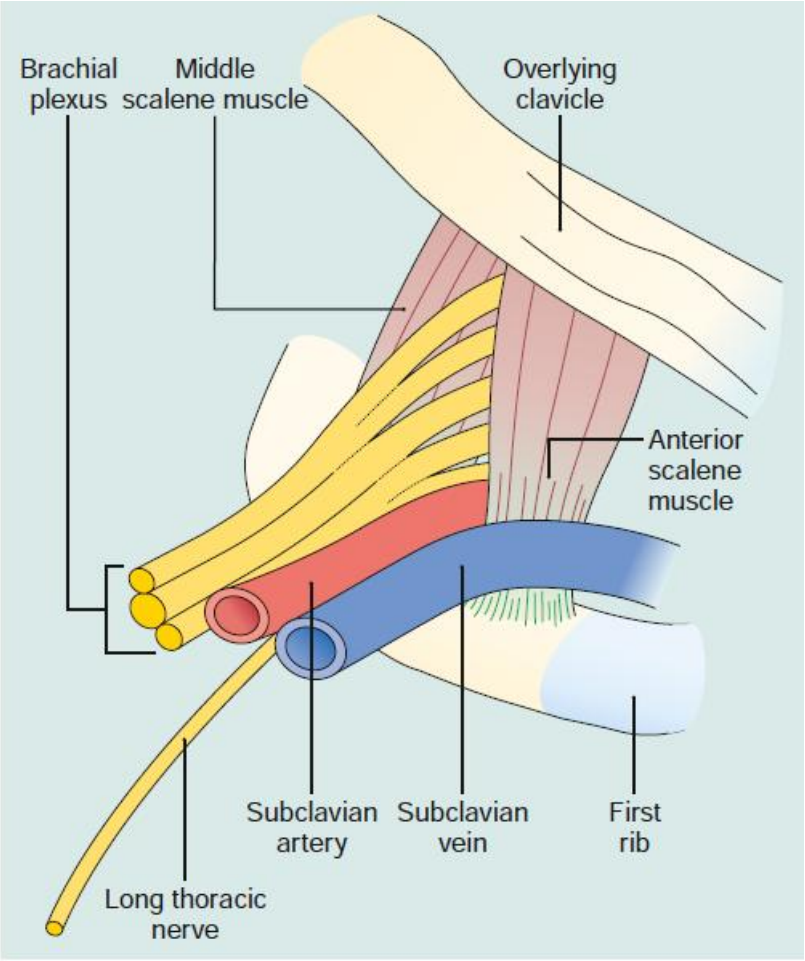


Figure: 1.1. Normal anatomy of Thoracic Outlet

The anatomic site is structurally unique in at least two regards: (i) the neurovascular structures are confined between two movable bony structures, the clavicular portion of the shoulder girdle and the first rib of the thoracic cage, and (ii) the neurovascular bundle is traversed (and consequently subdivided) by a normal anatomic structure, the anterior scalene muscle, which can function either as a postural muscle of the neck or an accessory muscle of respiration (Figure. 1.1).

During development, the C7 rib forms, then regresses to the C7 transverse process. Various stages in this evolution range from a complete C7 rib to rudimentary forms associated with a fibrocartilagenous band.[18, 19] The only radiologic indication of this residual band may be an enlarged C7 transverse process.[20]

The important causal relationship between supernumerary cervical ribs and compression of the subclavian artery was recognized in the earliest descriptions and remains the most durable concept after more than a century of clinical observation.

1.3.2. Embryologic considerations

The abdominal, thoracic, and cervical musculature develops from the hypomeric portion of the paraxial and epaxial mesoderm. The scalene and prevertebral muscles in the neck correspondto the intercostal and ventrolateral abdominal musclesin the thorax and abdomen, respectively.[21]

In the embryo, plates of axially running muscle segments differentiate into the discrete muscle groups seen in the adult. The subclavian artery, which is the artery of the seventh cervical segment, as well as the spinal nerves from C5 to T1, pierce the muscle plates in the cervical segment much the same as the intercostal nerve and artery do in the thoracic

segments. The growth of the limb bud and development of the pectoral girdle then lead to the particular structural changes seen in this region.

The important causal relationship between supernumerary cervical ribs and compression of the subclavian artery was recognized in the earliest descriptions and remains the most durable concept after more than a century of clinical observation. [22] Cervical rib development, for example, is determined by the formation of the spinal nerve roots. The regression of the C5 through C7 ribs is occasioned by the rapid development of the enlarging roots of the brachial plexus in the region of the limb bud. In cases of a cervical C7 rib, there is generally a prefixed plexus with only a small neural contribution from the T1 nerve root. The inhibition to rib development at that level is lost or reduced, and the size of the cervical rib is then related to the extent of contribution of this T1 root to the brachial plexus. [23]

1.4. ETIOLOGY

Arterial TOS always associated with a bony abnormality, the commonest being the presence of cervical rib, closely followed by the anomalous first rib. Even the length of the cervical rib matters. If the cervical rib is measured 5.6 cm or greater, the subclavian artery passed over the cervical rib. If the rib measured less than 5.1 cm, the artery crossed over the first rib, an observation that helps clarify the likelihood of arterial injury. The relative frequencies of anatomic abnormalities are shown in Table 1.1.

Abnormality	Frequency (%)
Cervical rib	63
Anomalous 1st rib	22
Fibrocartilaginous band	10
Clavicular fracture	4
Enlarged C7 transverse process	1

Table 1.1 -- Relative Frequencies of Anatomic Abnormalities Causing Arterial Thoracic Outlet Syndrome

Several other bony abnormalities are found in association with TOS. Posttraumatic changes following clavicular or first-rib fractures are commonly reported, with callous formation at the clavicle and pseudoarthrosis of the first rib (Figure .1.2). Malunion of clavicular fractures may cause SCA compression, either by the soft tissue swelling or by the abnormal position.

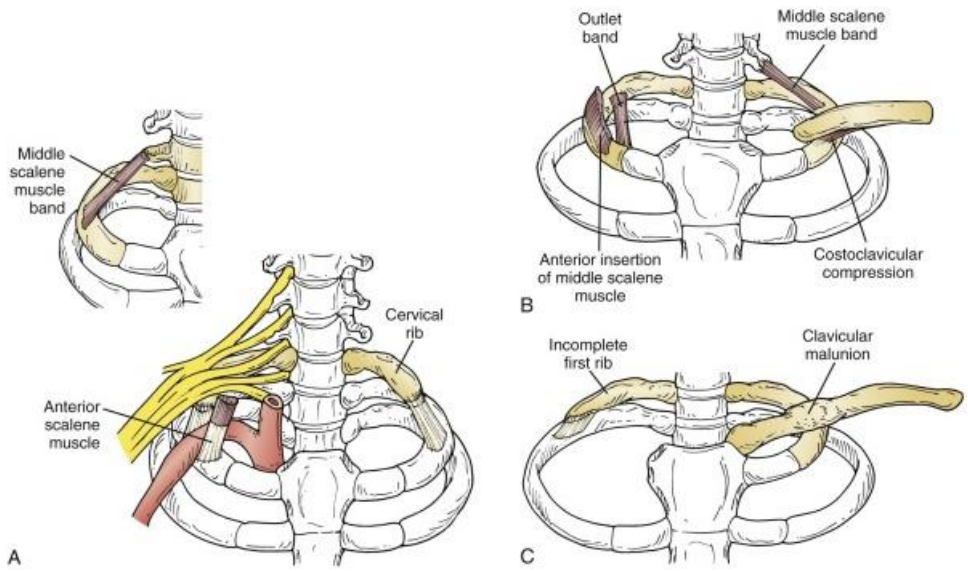


Figure: 1.2. Pathologic conditions commonly associated with arterial TOS. A, Cervical ribs with associated fibrous bands and a middle scalene muscle band. B, Fascial bands and anomalous muscle insertions. C, Incomplete first rib (anomalous first rib) and clavicular fracture callus.

Elongated C7 transverse processes are also occasionally seen. These changes can often be appreciated radiographically. Most TOS cases are associated with some form of soft-tissue anomaly. The classification system of Roos is the most thorough, with 10 distinct anomalies with several subtypes observed intraoperatively (Table.1.2).

Table: 1.2. Roos Classification System of Anatomical Variations in Anatomical Pathology of TOS

Type I	Incomplete cervical rib; band beneath T1 root attached to first rib
Type II	Abortive cervical rib with band to first rib
Type III	Accessory muscle between neck and tubercle of first rib; separates T1 nerve and the subclavian artery
Type IV	Large middle scalene compressing T1 nerve root; pins nerve to the vertebral body (ulnar symptoms)
Type V	Scalenus minimus muscle attaching to the first rib behind the scalene tubercle
Type VI	Scalenus minimus muscle attaching to the endothoracic fascia covering the cupola of lung
Type VII	Band extending from the middle scalene to the costal cartilage or sternum
Type VIII	Band from middle scalene under the subclavian vein; associated with Paget-Schroetter syndrome
Type IX	Web filling the inner curve of the first rib
Type X	Double band from cervical rib attaching to the cupola with a band to the costocartilage or sternum

1.5. PATHOPHYSIOLOGY

In aTOS, the pathophysiology is based on the effects of arterial compression by an anomalous first rib, cervical rib, or anterior scalene muscle. Subclavian artery stenosis produces fluid hemodynamics that results in post-stenotic dilatation or aneurysm formation, mural thrombus, and distal embolization. Arterial complications of TOS are associated with

bony abnormalities in almost all cases. Cervical ribs which are short, broad, and complete, by articulating with first as a peudoarthrosis tend to cause subclavian artery damage. [24] This differs from the longer, thinner, and incomplete cervical ribs generally associated with neurogenic TOS. The subclavian artery is pushed forward by the cervical rib, where it is compressed between the first rib and the anterior scalene muscle. This compression causes injury to the inferior aspect of the third segment of the subclavian artery, which may lead to localized intimal damage or post-stenotic dilatation. Less common causes of arterial TOS include anomalous first ribs, hypertrophic callus from healed clavicle fractures[25] and fibrocartilaginous bands associated with the anterior scalene muscle. [26] The post-stenotic dilatation associated with chronic arterial compression may progress to aneurysmal change, whereas localized intimal damage may lead to embolization or thrombosis.

1.6. CLINICAL FEATURES

1.6.1. SIGNS AND SYMPTOMS

Because subclavian artery compression can lead to several injuries, its presentation is the most varied of the three forms of TOS. Damage to the subclavian artery itself can lead to anywhere from a small stenosis to aneurysm formation or complete occlusion. Each of these can then have its own sequelae secondary to embolization or thrombosis or the extremely rare rupture of a subclavian aneurysm. Patients are commonly misdiagnosed with collagen vascular disease because of the cold sensitivity, Raynaud's phenomenon, and other symptoms. These patients may go on to have frank ischemic conditions of the hands, with paronychial ulcers or fingertip gangrene. If the subclavian artery is completely occluded, patients may present with early fatigue of the involved side. This can be in the form of crampy pain with exercise and has led to the term arm claudication. The most common manifestation is hand ischemia as a result of microembolization. However, arterial TOS can

be associated with less dramatic symptoms, and many cases go unrecognized because the condition tends to occur in young patients without atherosclerotic risk factors. Early in the disease process, patients may have mild symptoms of exertional arm pain or unilateral Raynaud's syndrome. Moderate to severe exertional pain may be associated with subclavian artery thrombosis. Occasionally, a subclavian artery aneurysm may be palpable in an asymptomatic patient. Retrograde propagation of thrombus from the subclavian artery may cause rarely cerebrovascular accidents. [27-31]

1.6.2. CLINICAL ASSESSMENT

Clues to the diagnosis of arterial TOS include young age of the patient and the tendency for symptoms to be unilateral, which helps differentiate the condition from systemic pathologic states. Deep-tendon reflexes, grip strength, and pulses should be routinely assessed. Palmar hyperhidrosis should be noted if present. The directed physical examination should consist of measurement of blood pressure in both upper extremities and auscultation for bruits in the supraclavicular fossa. A bruit may be elicited on shoulder abduction or the overhead arm position if it is not present in the relaxed position. Specific findings on physical examination include a palpable cervical rib or a pulsatile supraclavicular mass. Evidence of microembolization to the hand may also be present, including digital ischemia or splinter hemorrhages.

The most used TOS test is probably the elevated arm stress test (EAST), which was originally described by Roos and Owens in 1966 as a means for eliciting upper extremity claudication and neurological symptoms.[32] In the test, patients are asked to completely elevate the shoulders and arms (hold-up position) and then to repeatedly clench and unclench their hands. This positioning is designed to constrict the costoclavicular space and by many reports will bring on weakness and paresthesia in the ulnar and median nerve distributions in patients

with TOS within 3 minutes. Its proponents argue that it is specific for TOS and that the time of onset of symptoms correlates with the severity of TOS. In addition, it is felt by many that the test is good for reproducing the symptoms that patients suffer while using their upper extremities at work. Attention should also be made to the color of the hands during the EAST, as one may become pale and ischemic if arterial compromise is present.

Auscultation of upper-extremity arteries should include comparison of blood pressure in both arms and examination of the supraclavicular fossa for bruit. A difference in arm pressures of more than 10 mm Hg indicates a hemodynamically significant innominate, subclavian, or axillary artery stenosis on the side with the diminished pressure. Because collateral flow to the arm is extensive, a proximal subclavian stenosis may be present in an asymptomatic individual with palpable pulses at the wrist. If the patient has symptoms suggesting arm claudication, the arm should be exercised for 2 to 5 minutes and the brachial pressures rechecked. With this provocative maneuver, the brachial pressure will decrease if a significant arterial stenosis exists. When pulses are not palpable, continuous wave doppler can be used to assess arterial signals and measure arm and forearm pressures. Doppler signals can normally be heard over the thenar and hypothenar eminences, as well as over the palmar arch of the hand.

1.7. DIAGNOSTIC EVALUATION

Most surgeons routinely dealing with the disorder require at a minimum a physical examination consistent with the symptoms, cervical films to rule out disc disease, and a chest radiograph to visualize any bony abnormalities. Various other tests may be applied in different clinical situations or when the diagnosis is not clear. Different specialists also can

have differing approaches to the diagnosis, and the need for invasive or expensive tests is an area of considerable debate.

1.7.1. COMPRESSION MANEUVERS

Compression maneuvers are of historical interest only, because none is accurate. The tests of importance are the Adson test [33] and the abduction–external rotation test, also referred to as the elevated arm stress test popularized by Roos and Owens. [34]

1.7.2. Noninvasive Vascular Laboratory Studies

1.7.2.1. Duplex Ultrasonography

Duplex ultrasound examination of the subclavian and axillary arteries may demonstrate aneurysmal changes or elevated flow velocities correlating with a compressive stenosis.

1.7.2.2. Pulse Volume/Segmental Pressure Recording

Pulse volume or doppler segmental pressure recordings taken at multiple levels in the upper extremities can help localize the level of arterial obstruction if embolization has occurred as a result of arterial TOS. Reduced digital waveforms in the affected extremity and normal contralateral findings indicate arterial insufficiency consistent with stenosis or distal embolism.

1.7.3. RADIOLOGY

1.7.3.1. Roentgenography

Chest radiographs, including cervical spine views, will often demonstrate the offending bony pathology. Cervical ribs, elongated transverse cervical processes, and large clavicle fracture

calluses are easily seen. The cervical rib is diagnosed in cervical radiograph, by the following criteria: 1.The rib should abut from 7th cervical vertebrae transverse process. 2. It should not articulate with sternal manubrium. The cervical rib may be complete, when it articulate with the first rib or incomplete and rudimentary. In incomplete type, there may be a fibrous band connecting it to the first rib. Poorly developed cervical ribs may not be picked up by normal chest radiograph, but can be clearly visualized by digital radiographs.

1.7.3.2. ARTERIOGRAPHY

Arteriography is helpful in defining the severity and extent of large vessel occlusive disease of the upper extremity although it is not indicated in all such cases. Specifically, arteriography defines the location of the occlusive disease and provides information regarding the runoff to the forearm and hand. Arteriography is not necessary to diagnose vasospastic disorders but may be useful to rule out large-vessel occlusive disease like aTOS when Raynaud's phenomenon is complicated by finger ulcers. When performed, arteriography must show the entire upper-extremity vasculature from its origin (i.e., innominate on the right and subclavian on the left) to the digital arteries. Failure to obtain complete upper-extremity arteriography is a common reason for a missed diagnosis such as digital occlusions due to an ulcerated atheroma in the proximal subclavian artery. Arteriography can be done in the following three ways.

1.7.3.3. Computed Tomography

Computed tomography with intravenous contrast-enhanced angiography (CTA) is a useful test to secure the diagnosis, identify the exact point of compression and the extent of arterial pathology, to evaluate the distal arterial tree and aid surgical planning.

1.7.3.4. Magnetic Resonance Angiography

Although magnetic resonance angiography (MRA) may be an acceptable substitute for CTA or catheter-based angiography in some centers, the sensitivity of MRA for diagnosing arterial TOS appears to be low. Two reports of MRA in patients with arterial symptoms had a 37% and 42% incidence of false-negative findings. [35]

1.7.3.5. Catheter-Based Angiography

Upper extremity arteriography represents the "gold standard" for evaluation of arterial TOS. This test is important in operative planning because it localizes the exact point of arterial compression, provides an assessment of the nature and extent of arterial damage, and permits evaluation of the distal circulation. To assist in operative planning, runoff images should be obtained to identify normal anatomic variants, as well as acquired abnormalities.

1.7.4. LABORATORY INVESTIGATIONS

No specific laboratory tests are necessary to diagnose arterial TOS, but to exclude systemic causes such as vasculitis or connective tissue disorders. Since systemic diseases so often underlie vasospastic disorders and upper-extremity ischemia, a number of screening laboratory tests should be considered. A platelet count should be done, since thrombocytosis can mimic Raynaud's phenomenon. An elevated sedimentation rate should raise suspicion of a systemic illness. Since serum protein abnormalities may be associated with vasospasm, a serum protein electrophoresis should be performed and cryoglobulins, macroglobulins, and cold agglutinins should be checked. Basic immunologic tests should include antinuclear antibody, rheumatoid factor, and lupus erythematosus tests. If scleroderma is suspected, a skin biopsy in an affected area may confirm the diagnosis or a barium esophagogram may reveal characteristic esophageal dysfunctions.

1.8. TREATMENT

In arterial TOS, there is no role for conservative management for symptomatic patients, unlike in neurogenic TOS. The natural history of arterial abnormalities is not understood completely in asymptomatic patients. There seems to be little risk of complications in patients with simple compression without evidence of arterial involvement. So, watchful waiting and periodic monitoring with the use of noninvasive tests such as ultrasonography may be recommended in some asymptomatic cases. In high-performance athletes, such as professional tennis and baseball pitchers, who use frequent overhead arm movements aggressive physical therapy and modification of arm movements may be helpful to reduce thoracic outlet compression.[36]

1.8.1. SURGICAL TREATMENT

Surgical treatment is indicated in all symptomatic patients and in those asymptomatic patients with arterial involvement.

1.8.1.1. PRINCIPLES OF SURGICAL TREATMENT

The aim of surgical management in arterial TOS has three different but interlinked componenets; to relieve arterial compression, to remove the source of embolism and to restore the distal arterial tree circulation. Resection of cervical rib, first rib, anterior scalene muscle, or any soft tissue or bony anomalies causing impingement at the outlet, relieves the arterial compression. Subclavian aneurysm resection, repair of aneurysm and repair of the

diseased intima helps to remove the source of embolism. Thrombolysis, thrombectomy, thrombointemectomy, or distal bypass, are some of the ways to restore the distal circulation.

1.8.1.2. Selection of Treatment

The severity of subclavian artery damage and the condition of the distal upper limb circulation decides the appropriate treatment. This is simplified by Scher classification, which gives guidelines for appropriate treatment according to the stage and presence of damages. According to Scher, an increase in more than twice than the diameter of the adjacent normal segment of the artery is defined as aneurysm and less than twice defined as post-stenotic dilatation. [37, 38]

Scher classification describes 3 stages. Stage I describes compression of the artery with minor post-stenotic dilatation, which to be managed by decompression procedures alone. Stage II describes arterial damage, presence of either aneurysm or mural thrombus, which to be managed by decompression of outlet and reconstruction of the subclavian artery. Stage III includes patients with distal embolic manifestations, which to be managed by decompression of outlet, reconstruction of the subclavian artery and either thrombolysis or thrombectomy.

1.8.1.3. Operative Planning and Strategy

Decompression of the thoracic outlet by removing any structures causing impingement at the outlet is the first step in the strategy of management. There are two different approaches – supraclavicular and transaxillary approaches. Even though transaxillary approach gives complete visualization of the first rib, vascular manipulation and reconstruction becomes

difficult (Figure 1.3). So, it is commonly used in the treatment of neurogenic TOS, where vascular intervention is nil. [39]

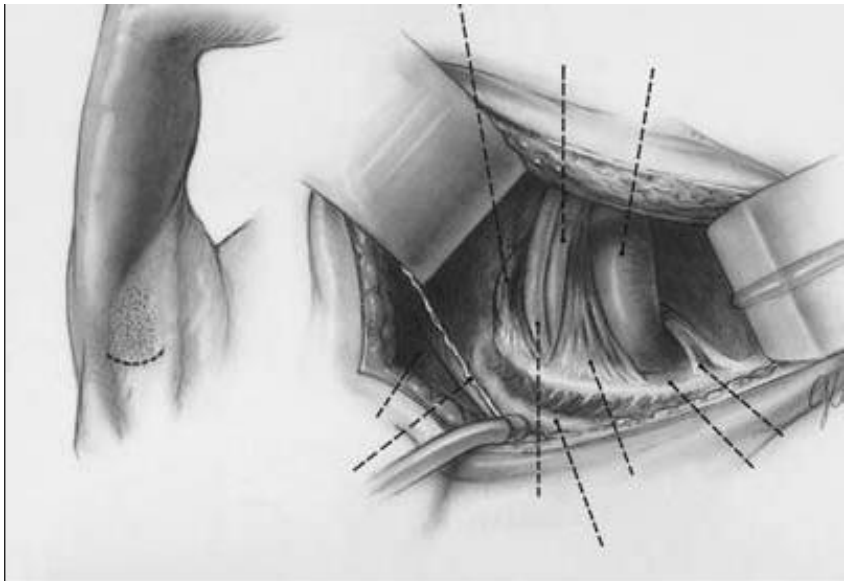


Figure: 1.3. Transaxillary approach to first rib

The supraclavicular approach allows identification of the cause of compression, resection of the cause and first rib, and subsequent vascular reconstruction. In addition to the supraclavicular approach, sometimes infraclavicular exposure may be needed for complete exposure of large subclavian aneurysm and for vascular reconstructions involving axillary artery. Robicsek et al described a modified approach, by a single incision for the treatment of thoracic outlet syndrome. [40]

The subclavian artery anomalies are repaired either by simple resection and primary anastomosis or replacement by interposition grafts. The conduits used are either autogenous

veins like great saphenous vein or femoral vein [41], or synthetic grafts such as ringed polytetrafluoroethylene, or Dacron.

Open surgery is the preferred method of treatment in the management of arterial TOS. In the supraclavicular approach, after mobilization of the scalene fat pad, the phrenic nerve should be identified and carefully elevated before the anterior scalene muscle is divided. The long thoracic nerve should be identified and protected during division of the middle scalene muscle. Attachments are freed via an extraperiosteal approach to prevent recurrent symptoms from reossification of the periosteal bed. Division of the first rib should be performed under direct vision to minimize the possibility of damage to the brachial plexus. After the first rib is divided just distal to the tubercle, the divided rib can be held as a lever to aid in clearing the overlying vessels.[42]

Endovascular options are available for subclavian artery repair, combined with open surgical decompression of the thoracic outlet.[43, 44] In selected patients, early reports of endovascular management are encouraging, but long term data needed to validate this approach.

Choice of distal revascularization procedure depends on the stage of upper extremity ischemia. Patients with mild ischemia may benefit from preoperative thromobolysis or catheter directed thrombolysis. Presence of sensory or motor deficit is an indication for immediate surgery, including embolectomy, either transsubclavian or transbrachial. In acute on chronic ischemia, distal bypass may become necessary. Sympathectomy may be considered in cases of ischemic causalgia. [45]

Post-operative care includes physical therapy and range-of-motion exercises. Follow-up includes serial physical and duplex ultrasound examination. Outcome success rate is determined by symptom relief, recurrence rate, patency rate of graft, and limb salvage rate. Limb salvage rates in Scher stage I and II should be 100%. Minor finger amputations may be done in Scher stage III, bur major amputations are definitely uncommon. [46]

1.8.2. ENDOVASCULAR MANAGEMENT

In this evolutionary period of computer enhanced instrumentation, application of Robotic instrumentation during endoscopic transaxillary first rib resection has a greater role to play. Endoscopic transaxillary first rib resection procedures are completed with the help of robotic arm with integrated voice control instrumentation. [47]

1.8.2.1. Surgical Procedure

A supine position was used during a supraclavicular approach for a cervical rib resection or total anterior scalenectomy. A lateral position with 35° flexion of the leg was used for the transaxillary approach. Standard anesthesia methods were used and a dual endotracheal tube preferred.

1.8.2.2. Surgical Access

During the procedures, a 30 mm mini incision is performed transversely at the base of the axilla. A separate 10 mm port placement incision is made in the anterior axillary line, for the introduction of the endoscope. Port placement is between the pectoralis major and the latissimus dorsi musculature. Particular attention is paid to the long thoracic nerve, next to the latissimus dorsi. Creation of the space is initiated using a medium endovein harvesting device with a 30°, 5 mm scope. The space is dissected in a subpectoral fashion; the sternum, first rib,

and second rib are individualized. Placement of a retractor in a subpectoral fashion just anterior to the axillary vein and slight retraction and hyper adduction of the arm by the assistant help to further extend and maintain the working area.

1.8.2.3. Engagement of the Robotics

The robotic arm can be placed either in a single or three levels, depending on the instrument used. It can be placed in front of the patient with a 20–30° pivotal rotation cephaloid or at three levels: the endoscope-camera complex (8 mm), right-arm robotic instrumentation (5 mm), and left-arm instrumentation (5 mm). The robotic system approaches the patient head on, but slightly (15°) tilted posteriorly.

1.8.2.4. Dissection of Soft Tissue, First Rib, and Space Invasion with Collapse of Lung

The intercostal muscles between the first and the second rib are excised, and the parietal pleura is visualized and purposely opened. The lung is collapsed using the dual endotracheal tube. Owing to the reduction of the lung field, there is now a noticeable increase in the endoscopic working space.

1.8.2.5.Disengagement of the First Rib and the Concept of Floater Rib

Careful attention is made to protect the vein as the first rib is disconnected anteriorly from the sternal cartilage. As the first rib is freed anteriorly, the rib can be mobilized superiorly and inferiorly—thus, the concept of a floater rib. The attachments of the scalenus muscle fibers (anterior and medius) are easily individualized. Cervical bands become stretched, making them easier to identify and safely excise, thus relieving pressure on the neurovascular

structures. The dissection is carried posteriorly all the way to the transverse process of the T I vertebra. The various cervical bands are resected as they are encountered. The rib is resected in small pieces by rongeurs and is considered completely resected when the soft white cartilage is visualized at the transverse process. This is the best indicator of complete resection of the rib posteriorly, as is the sternal cartilage the best indicator of complete excision anteriorly.

1.8.2.6. Closure

Two red rubber catheters are left in the pleura cavity, and the lung is re-expanded. Subcuticular wound closure is completed using absorbable sutures. A chest radiograph is taken in the operating room.

1.9. COMPLICATIONS

Major complications occur from all operations to decompress the thoracic outlet area regardless of the surgical approach. Injury to the subclavian artery and vein, brachial plexus, phrenic nerve, and long thoracic nerve are the most common serious complications. Less common are injuries to the thoracic duct and cervical sympathetic chain. Injuries to cutaneous nerves from either transaxillary or supraclavicular approaches are common. Plexus injury occurs from excessive traction, which at the time may not seem excessive. Plexus injury can also occur when a clamp on the subclavian artery to control bleeding accidentally includes a nerve of the plexus. Plexus injury makes symptoms worse in 1 percent of patients. The incidence of temporary phrenic nerve injury during supraclavicular approaches is 6–10% because the phrenic nerve is often in the middle of the field and is very sensitive to even mild retraction. [48]

Aims and Objectives

1. AIMS AND OBJECTIVES

The aim of this study was to review our operative experience and to assess the symptomatic outcome of patients with arterial thoracic outlet syndrome who underwent decompression of the thoracic outlet.

1. To study the patient factors and their symptoms

2. To analyze the type and site(s) of artery lesion

3. To analyze the causative compressive agents

4. To analyze the methods of surgical exposure and methods of decompression

5. To study the techniques for repairing arterial lesions at the thoracic outlet

6. To analyze the post operative outcome

PATIENTS & METHODS

2. PATIENTS AND METHODS

2.1. DESIGN

This study is a prospective study.

2.2. SETTING

This prospective study includes analysis of 30 patients who were admitted in the ward 49, Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Chennai – 3, with arterial lesions in the upper limb due to thoracic outlet syndrome, from 2nd August 2010 to 1st January 2013.

2.3. METHODS

2.3.1 .SAMPLE SIZE

Study population is 30.

2.3.2 .INCLUSION CRITERIA

30 patients who were admitted with complaints suggestive of arterial lesions resulting from compression by bony or soft tissue elements at the thoracic outlet , at ward 49, Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Chennai – 3, from 2nd August 2010 to 1st January 2013, are included in this study.

2.3.3. EXCLUSION CRITERIA

Patients with atherosclerotic lesions in upper limb and primary Reynaud's phenomenon are not included in this study.

2.4. PROTOCOL ON ARRIVAL

On admission all patients are evaluated for the emergency nature of the disease. If signs of ischemia and distal embolisation are present, patients are further evaluated by detailed clinical examination to confirm the level of the ischemia, and full dose of heparin is started to stop the progress. The patient will be evaluated by radiological methods to confirm the presence of compression agents and level of arterial lesion. These patients underwent routine blood and urine examinations.

After obtaining anaesthetic assessment, the patient will be posted in the next elective theatre list. If the patient is presented with complaints of non-emergency nature, he/she will be evaluated by duplex scan and computed tomography angiogram (CTA) whenever relevant. All patients were approached by supraclavicular route. After incising skin and platysma, anterior scalene muscle is divided and subclavian artery control is taken. In all cases, cervical rib is excised in piecemeal. Any other bony prominences or soft tissue structures causing compression is tackled. According to the type of arterial lesion, various procedures such as aneuryssmorraphy or aneurysm excision with interposition graft- venous or synthetic, are done. According to the level of embolisation, either subclavian artery transembolectomy

and/or transbrachial embolectomy are done. All patients are evaluated for postoperative improvement. All patients are followed up monthly till the study period.

2.5. PROCEDURE

On selection, each case is studied in detail and the data was collected by using the proforma shown in the next section.

2.6. OBSERVATIONS

The data obtained from the Proforma are entered in computer in Excel format. The data is presented in appropriate charts, table, graphs and figures etc. Analysis of data is done and statistically interpreted.

PROFORMA

1.. PROFORMA

Name Age Sex

I P No Occupation

Presenting complaints : bilateral / unilateral – right / left

SYMPTOMS	Y/N	DURATION
Pain		
Work claudication		
Colour changes		
Cold limb		
Paresthesia		
Raynaud's syndrome		
SIGNS		
Motor deficit		
Sensory deficit		
Tissue loss		
Signs of microembolism		
Ischeamia – Class I / II A / II B / III		
ASYMPTOMATIC		

Tobacco use YES / NO ---------- Yrs

Co-morbid conditions

HTN	DM	CAD	CVA	COPD	BA	EPILEPSY

	RIGHT	LEFT	BRUIT
CCA			
SCA			
BRACHIAL			
ULNAR			
RADIAL			

RADIOLOGY

X RAY

C T ANGIO

TREATMENT : Medical / Surgical / conservative

OPERATIVE DETAILS:

1. Cx rib : Complete/incomplete Bilateral / Unilateral – Right / Left

2. Other compressive agents : bands/ callosity / C7 / fibrous tissue / 1st Rib

3. Site of Artery lesion: SCA / Aux A / Br A / Ra A / Ul A

4. Artery lesion : Nil / Dilatation / Aneurysm / Thrombus

4. Surgical exposure : Supraclavicular / Infraclavicular / Trans axillary

5. Any other finding:

6. Procedure done ;

7. Arterial repair done : Thrombectomy / embolectomy / aneurysmorraphy / Tailoring & direct closure / interposition graft - venous / synthetic

OUTCOME

1. Symptomatic improvement 2.Arterial Pressure improvement

3. Limb salvage : Yes / no

OBSERVATIONS and RESULTS

4. OBSERVATIONS & RESULTS

A total number of 30 cases are studied in this study period. The various observations in relation to sex, age, side of lesion, clinical features, site and severity of arterial lesion are analysed.

4.1. CLINICAL FEATURES

4.1.1. AGE DISTRIBUTION

The study group included representatives from age group 16 to 67 years. The age incidence is given in Table No.2.1

Table . 2.1 - Age Distribution

Age group	number	percentage
< 20	5	17
21-30	9	30
31-40	7	23
41-50	5	17
51-60	2	7
61<	2	7

From this table, it is evident that maximum incidence is in the second and third decade. Nearly 53% of cases belong to this age group. Number of cases becomes few as age advances.

On sub-analysing the data, it is found that the incidence in females is one decade earlier than the males. About 75% of female cases occur before the age of 30 years. (Table.2.2)

Table.2.2 - Age distribution according to sex

AGE	MALE	FEMALE
< 20	1	4
21-30	4	5
31-40	6	1
41-50	4	1
51-60	2	0
60 <	1	1
Total	18	12

4.1.2. SEX DISTRIBUTION

Out of 30 cases studied, 18 are male patients and 12 are female. Males outnumbered females by about 3:2 times. (Table.2.3)

Table.2.3 - Sex distributions

Male	18	60%
female	12	40%

4.1.3. SIDE OF SYMPTOMS

Table.2.4. - Distribution of side

RIGHT	14
LEFT	16

There is a slight predominance of left side in our study. (Table.2.4)

Table.2.5 - Side distribution according to sex

SIDE	RIGHT	LEFT
MALE	6	12
FEMALE	8	4
	14	16

In analyzing the data further, it is a noticeable fact that the left side predominance in male is about 2:1, while it is a reversible order in females, with right predominance, about 2:1. (Table.2.5)

4.1.4. SYMPTOMS

Presence of supraclavicular swelling (Figure: 2.1) is not noted by any patients and not part of their presenting complaints. Claudication seen on 27 cases is the commonest clinical presentation. Acute limb-threatening ischemia with sensory and motor impairment is observed in 14 instances, digital gangrene is observed in six cases (Figure: 2.2), and vasomotor symptoms are observed in five cases (Figure: 2.3). In addition to evidence of arterial compression, nine patients in this study have neurogenic symptoms. The symptoms are more in the arterial lesions group than in the normal artery group. (Table.2.6)

Table: 2.6 - Symptoms

	nil	dilatation	aneurysm	total
Vasomotor	1	1	3	5
Claudication	7	11	9	27
Digital gangrene	0	4	2	6
ALI	0	7	7	14
Neurogenic	6	2	1	9

4.1.5. SCHER STAGE ON PRESENTATION

In this study majority patients present in advanced Scher stage. 17 patients (57%) presented in Scher Stage III, 37 patients (37%) in stage I and only 2 patients presented at stage II. All patients presenting at stage II and III have arterial lesions, while only one patient in Scher

stage I have any arterial lesion. 8 patients in Scher stage II and 9 patients in Scher stage III have aneurismal dilatation of the SCA. Patients with arterial involvement such as dilatation or aneurysm are more likely to present with advanced Scher stage. (Table.2.7)

Table: 2.7 - Scher stage on presentation and associated arterial lesion

SCHER stage	Nil	Dilatation	Aneurysm
1	10	1	0
2	0	1	1
3	0	8	9
Total	10	10	10

4.2. DIAGNOSTIC EVALUATION

4.2.1. RADIOLOGICAL INVESTIGATIONS

All patients had cervical x-ray, (Figure.2.4) most underwent duplex scan of neck and upper limb vessels. Only 3 patients are required to have CTA for planning for surgery (Figure. 2.5 & 2.6) and one patient required MRI to confirm soft tissue/band compression. (Table.2.8)

Table:2.8 - Investigations done

CXR	30
Duplex Scan	21
CTA	3
MRI	1

10 patients (33%) have right side cervical rib and 11 patients have left side, while 9 patients (30%) have bilateral. Even though all patients had unilateral symptoms, cervical x-ray showed that 9 of them have bilateral cervical rib (Table.2.9).

Table: 2.9 - Side of cervical rib

Right	10
Left	11
Bilateral	9

4.2.2. COMPRESSIVE AGENTS

Complete cervical rib with syntosis or arthrosis with 1st rib is the commonest lesion responsible in 17 cases, followed by incomplete cervical rib in 11 cases. Anomalous 1st rib is found in one patient and in two cases there are musculofibroligamentous lesions. (Table.2.10)

Table:2.10 - Types of compressive agents

	No	%
Complete cervical rib	17	57
Incomplete cervical rib	11	37
Anomalous 1st rib	1	3
Soft tissue	2	6

4.2.3. ARTERY LESIONAT THORACIC OUTLET

Presence of dilatation and a of dilatation and aneurysm of subclavian artery is present in 20 cases. Arterial occlusion is present in fifteen instances of which nine are in patients with an aneurysm. Of the 30 arterial lesion operated on, 19 are complicated by distal thromboembolism at one or more sites. (Table. .2.11)

Table 2.11 – Arterial lesion

LESION	NO	%
NIL	10	33
DILATATION	10	33
ANEURYSM	10	33
OCCLUSION	15	50

4.2.4. SITES OF DISTAL ARTERIAL LESIONS

Out of 15 patients who had thrombosis, the commonest site (66%) of distal occlusion is at brachial artery. (Table.2.12)

Table: 2. 12 - Site of distal occlusion

Site of lesion	NIL	Dilatation	Aneurysm	Thrombosis
Axillary artery	0	1	2	3
Brachial artery	0	7	6	10
Forearm arteries	1	2	2	2
Total	1	10	10	15

When there is arterial lesion like dilatation, aneurysm or thrombosis, there is presence of associated lesions in various distal arterial sites. But, when there is no arterial lesion, only one case has associated distal lesion.

4.3. TREATMENT

4.3.1. METHOD OF SURGICAL EXPOSURE

All cases are approached by supraclavicular approach, for cervical rib excision and arterial repair, so that the associated arterial lesion can be tackled in the same setting. In one patient, when the aneurismal disease extending into 1st part of SCA, lateral thoracotomy is done to take the control of 1st part.

4.3.2. TECHNIQUES FOR REPAIRING ARTERIAL LESIONS AT THE THORACIC OUTLET

In Scher 1 lesions, if there is no obvious arterial involvement, no arterial procedure is done. In most cases, endoaneurysmorraphy with thromboendartrectomy is done. Simple arteriotomy and direct closure is done in 5 patients. (Table.2.13)

Table: 2. 13 – Surgical Procedures done

PROCEDURE	No.
Endoaneurysmorraphy	1
Endoaneurysmorraphy and thromboendartrectomy	15
Vascular repair	4
Distal thrombectomy	18
Arteriotomy	5
No procedure	10

There are 4 cases, who underwent vascular repair. In one patient, resection and direct anastomosis is done, where other 3 patients need interposition graft. Autogenous vein graft is used in one patient and PTFE synthetic graft in 2 patients.

Most cases with thrombus underwent transsubclavian thrombectomy, through the same arteriotomy. In 18 cases where there is an additional disease process at distal level, distal thrombectomy through a separate brachial arteriotomy and distal arterial tree is cleared.

4.3.3. Resection of compressive agents

In all cases, the compressive bony component is removed (Table.2.14). First rib is not excised, except in one patient who has anomalous first rib. Any obvious soft tissue compression elements are also routinely removed for full clearance. Scalenotomy is not a routine procedure, but depends on the surgeons' choice.

Table: 2. 14 - Surgical decompressions at thoracic outlet

METHOD OF DECOMPRESSION	NO
Cervical rib excision alone	8
Cervical rib excision and scalenotomy	19
Excision of 1st rib	1
Cervical rib and soft tissue excision	1
Soft tissue excision	1

4.3.4. Clinical outcome

There is no perioperative or post operative mortality. Two patients need intercostal drainage tube in the immediate postoperative period, one for lateral thoracotomy and another for inadvertent opening of parietal pleura. Both tubes are removed within 4 days with no other morbidity. One patient had hematoma at the surgical site, which needed evacuation under anesthesia.

All patients except one had improvement in their symptoms objectively. The subjective improvement measured by improvement in the pressure. 16 patients had their pressure status improved, while 14 patients maintained their pre operative pressure. Out of 18 patients presented with absent pulse, 13 had their pulse reappeared in their brachial and 6 in forearm arteries. 5 patients had amputation: one major above elbow and 4 minor digital amputations. The one with above elbow amputation was admitted with Rutherford Class III ischemia, sensory and motor impairment up to elbow.

4.3.5. Follow-up details

All patients are followed up to the end of study period. The follow up period ranged from 2 years to 2 months. All patients are assessed clinically for any signs or symptoms of ischemia. The functional status of the limb and objective assessment of arterial system are done with clinical and radiological methods. No patients developed any new signs or symptoms of ischemia during the follow up period.

REPRESENTATIVE CASES

5.1. Case no 1

Mrs. S 62/F IP No.27421

62 year old female flower vender, admitted with history of colour change in left hand for 3 months and claudication pain left arm for 6 months. She uses sniff powder.

	Right	Left
CCA	N	N
SCA	N	++++
BRA A	N	_ 30
ULN A	N	_ no flow
RAD A	N	_ no flow

On admission, she has pulsatile, left supraclavicular swelling and chronic ischemic changes in the forearm.

Reynaud phenomenon was noted in her left arm on exposure to cold water. Cervical X-ray shows unilateral incomplete left cervical rib.

She underwent left cervical rib excision, subclavian artery intimothrombectomy, direct closure and distal transbrachial embolectomy.

She had complete symptomatic improvement and normal brachial and radial pulses.

5.2. Case No. 2

Mrs.T 47/F IP No. 106384/10

47 year old female presented with complaints of numbness, pain in right arm for 2 months. No history of previous claudication or giddiness.

On examination there is a pulsatile swelling in the right supraclavicular area with thrill and prominent bony cervical rib palpable in the left supraclavicular area.

	Right	Left
CCA	N	N
SCA	++++ thrill	N
BRA A	_ venous	N
ULN A	_ mono	N
RAD A	_ mono	N

No forearm muscle wasting. No evidence of acute/chronic ischemic changes in both upper arms.

Cervical X-ray revealed bilateral complete cervical rib.

Duplex scan shows aneurismal dilatation with partial thrombus in the 2nd part of subclavian artery, 3rd part completely occluded with thrombus, no flow in brachial artery, radial artery and ulnar artery, with only mono phasic flow in profunda brachii.

She underwent right cervical rib excision with resection and end to end anastomosis of subclavian aneurysm, distal thrombectomy, both transaxillary and transbrachial. She had postoperative hematoma at the surgical site, which was evacuated under anaesthesia.

She has a follow up of 2 years and no recurrence of symptoms in right side and no new symptoms in left side.

5.3. Case No. 3

Mr. D 49/M IP No. 40489/11

49 year old male tea master, reported with pain and inability to use right upper limb for 3 days. Not a K/C/O of DM/HTN/CAD/CVA. H/O smoking present for 20 years.

	Right	Left
CCA	N	N
SCA	++++	N
BRA A	_ no flow	N
ULN A	_ no flow	N
RAD A	_ no flow	N

On admission, right upper limb is cold up to elbow. Ischemic skin patches seen in the right forearm. Right wrist drop present. Sensory loss present up to mid 3rd of forearm. Right hand is gangrenous.

Cervical X-ray confirmed the presence of Right complete cervical rib.

He underwent right cervical rib excision, Subclavian artery endoaneurysmorraphy, right trans-brachial thrombectomy and forearm faciotomy.

As there is no improvement in the condition, he underwent above elbow amputation .

CLINICAL DISCUSSION

6. CLINICAL DISCUSSION

Although aTOS is a rare condition, early diagnosis and intervention is the key factor in preventing the morbidity associated with this syndrome. In this study 30 cases are discussed in detail.

6.1. PATIENT FACTORS

In our study, out of 30 patients, 18 are men and 12 are females i.e. 60%male and 40% female (Fig. 2.10). This is in contrast to the common belief that females are more commonly affected. In a report by Adson, it was 72% women and 23% men. [33] In other studies also, there is female preponderance attributed to the presence of cervical ribs in more females than males. But, the presence of cervical rib does not mean TOS and so, the increased number of cervical ribs in females cannot mean increased number of arterial TOS in females.

Out of 12 female patients, 9 (75%) are below 30 years. According to Kiessling, women in 2nd and 3rd decades of life are more prone for TOS, due to adoptive changes in the human muscle due to different physical activities. [49] In both sexes, the incidence of aTOS is decreasing as age increases (Figure. 2.11).

Figure. 2.10 - SEX

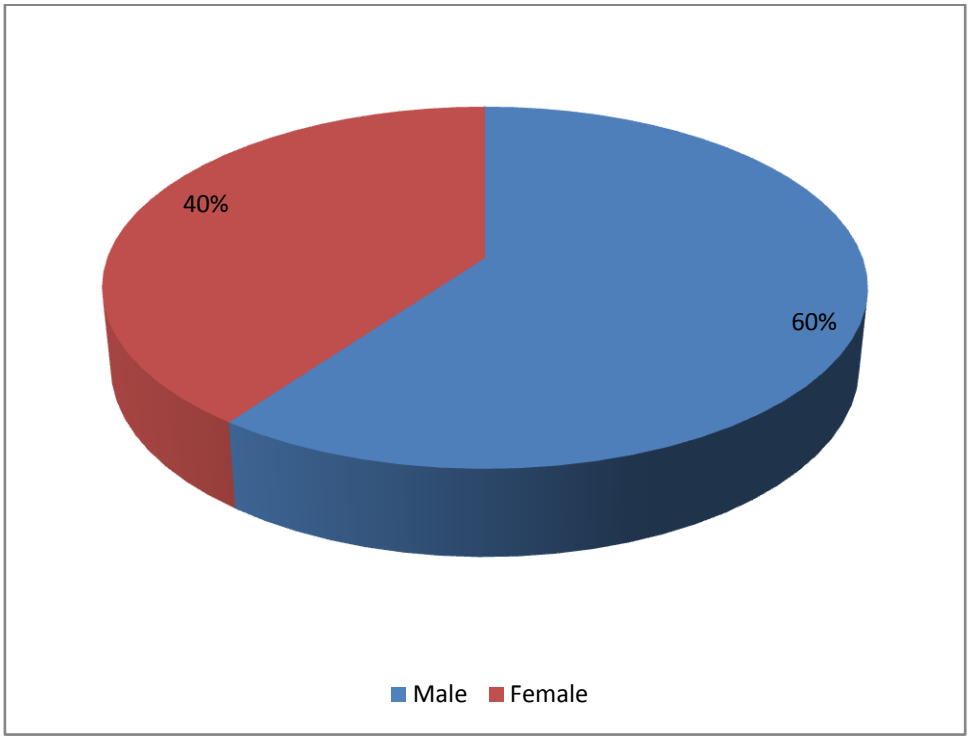
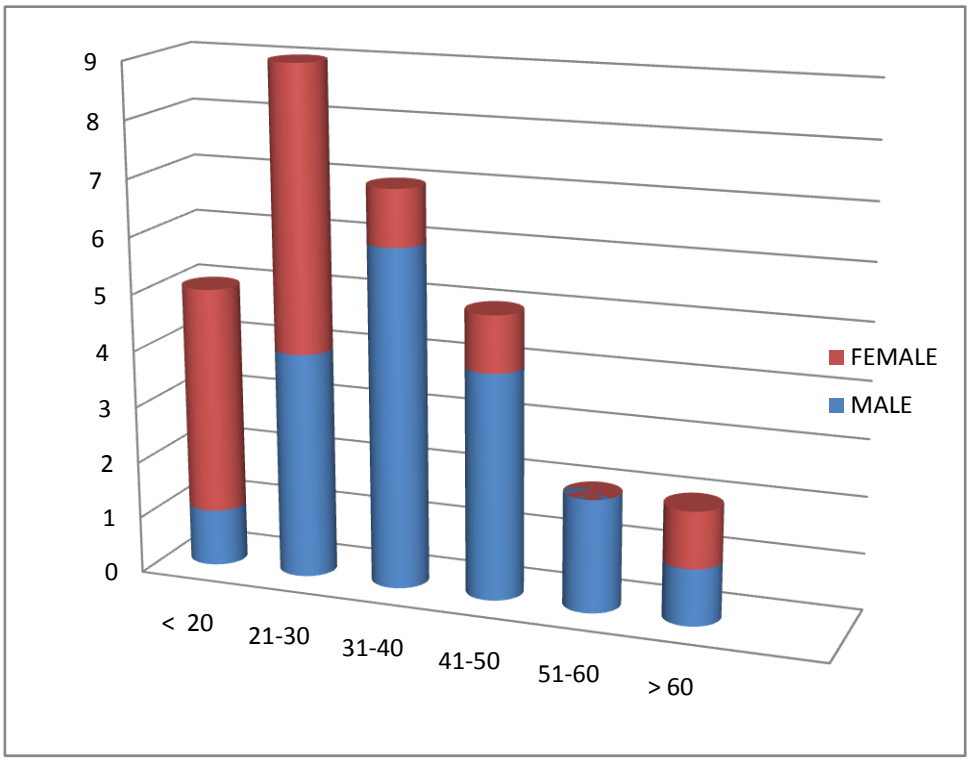
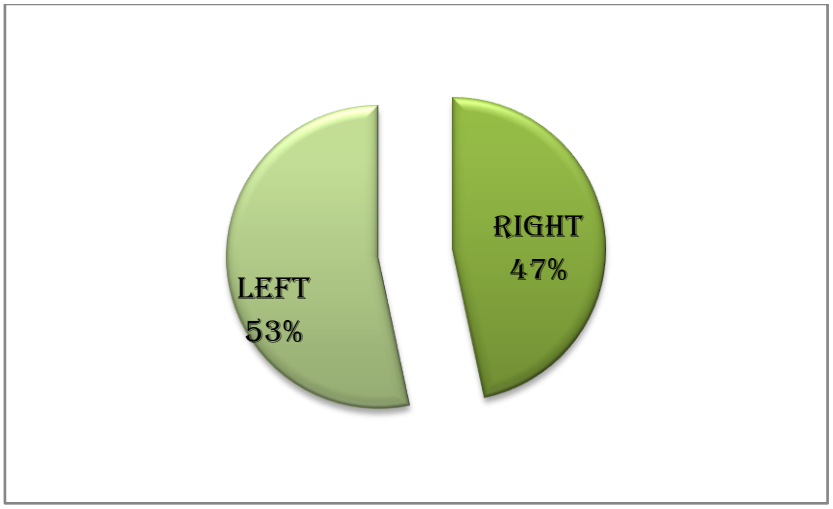


Figure .2.11 – Age distribution according to sex



There is a predominance of symptoms in left side in the present study, even though it is not significant statistically (Fig.2.12). 9 patients (20%) have bilateral cervical rib, which is less than reported earlier. In one study it is 67% [50] and in another study, it is 33.3%. [51]

Figure: 2.12. – Distribution of symptoms according to side



In analyzing the factor further, it is a noticeable fact that in females it is right side predominance (Fig.2.13). It is a well known fact that the incidence of aTOS in right side is more due to the increased incidence of right side cervical ribs. Figure: 2.13 – Side of symptoms distribution according to sex

Claudication is the commonest symptom, with 90% of patients having various degree of pain (Fig.2.14). The commonest presenting symptom is acute limb threatening ischemia (ALI) in 47% of patients. 5 patients reported with digital gangrene while 1 patient had Rutherford class III ischemia.

As the arterial lesion progresses from simple dilatation to aneurysm, there is increase in the severity of symptoms, at presentation. 9 patients (20%) have associated neurogenic component of pain also, and one patient is proven to have median nerve involvement by nerve conduction study. It is not uncommon to found patient presenting with neurogenic pain, but suspicion of arterial involvement should always be in the mind, whenever we come across any discrepancy in pulse status.

Scher staging help us in deciding the appropriate management. In our study, most patients presented in advanced Scher stage. 17 out of 30 patients presented with stage III (Fig.2.15). This high incidence may be explained by the fact that ours is a referral institute for vascular lesions. In 11 patients who presented in stage I, 10 patients have no arterial involvement. But, all 2 patients in stage II and 17 patients in stage III, have arterial lesion either dilatation or aneurysm of SCA. So, patients with advanced arterial disease are most likely to present in higher Scher stage and in limb threatening condition.

Figure. 2. 14 - SYMPTOMS

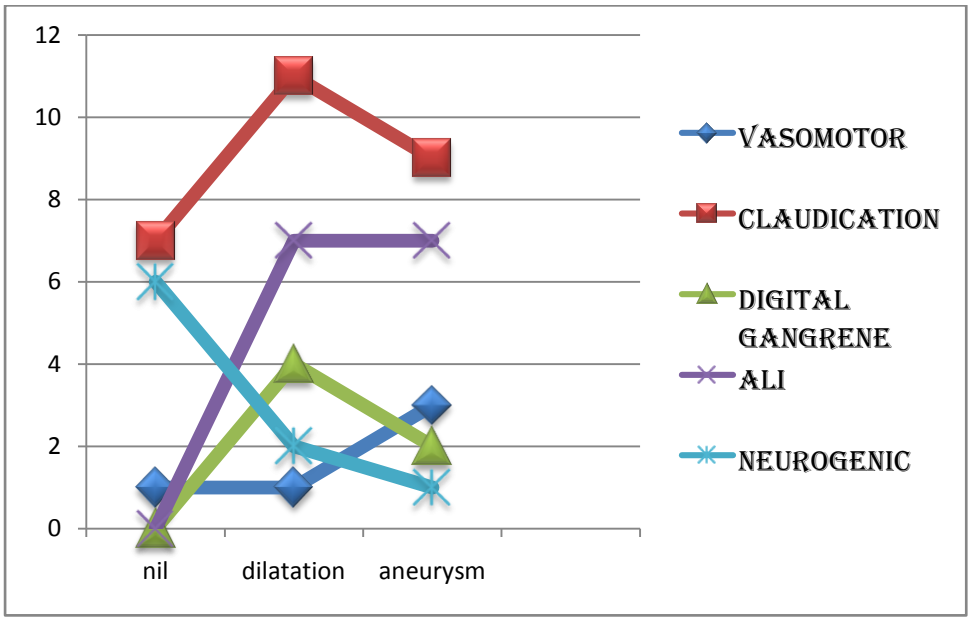
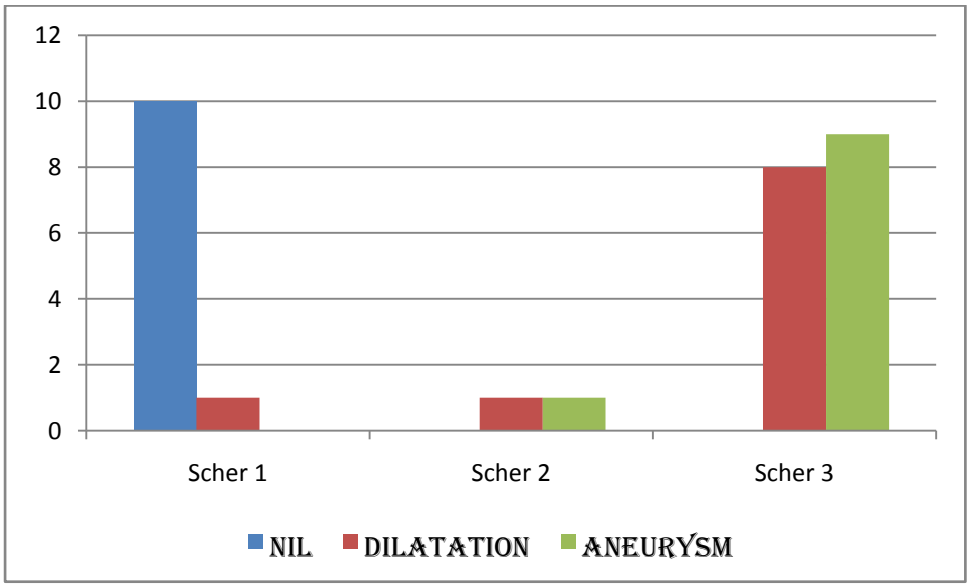


Figure.2.15: Scher stage according to arterial lesion



6.2. COMPRESSION AGENT

In aTOS, there is always presence of bony abnormality at the thoracic outlet. [52] The commonest compressive agent is cervical rib in 28 cases (93%). There is one case

with anomalous first rib and two cases of soft tissue compression, one band and another post traumatic inflammatory tissue around first rib (Fig.2.16).

Figure: 2.16 - Compression agents

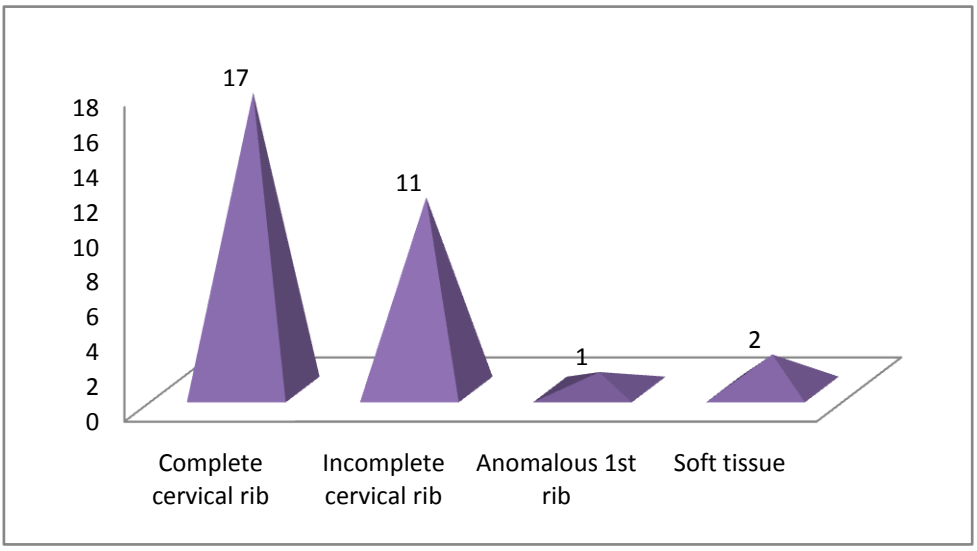
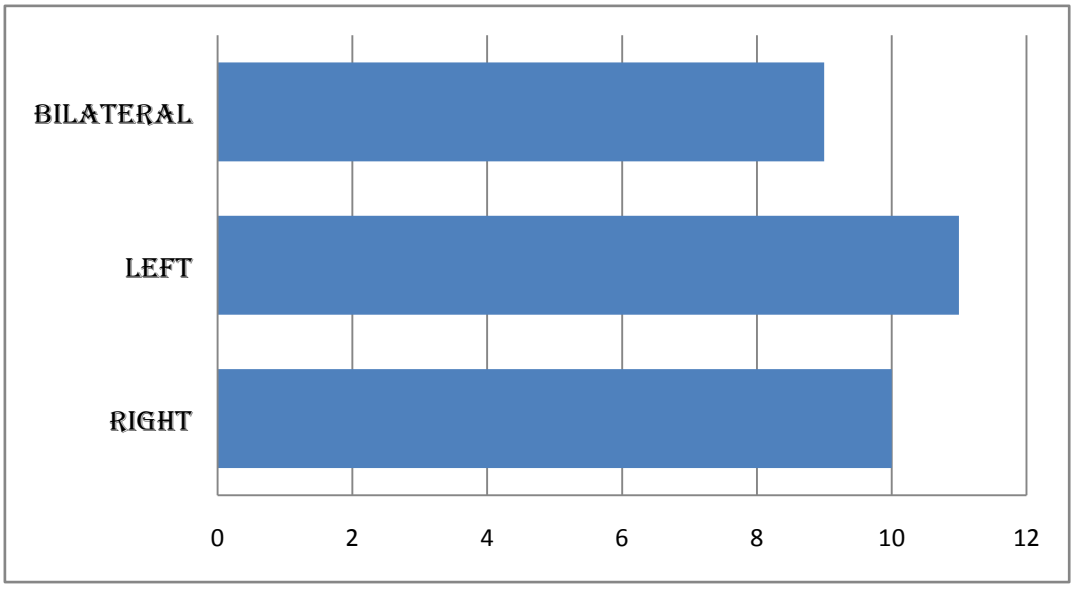


Figure:2.17 - Side of cervical rib



All the cases have cervical X-ray, which helped to diagnose the bony element compressing thoracic outlet. 21 patients (70%) underwent duplex scan of neck and upper limb arterial system to delineate the extent of arterial involvement and to diagnose the site of distal obstruction and occlusion.

Only 4 patients (10%) need further investigation, 3 underwent CT angiogram and one MRI. MRI is needed to confirm the presence of band causing compression at SCA.

The cervical rib is right side in 10 cases, left in 11 cases and bilateral in 9 cases (Fig.17). 30% of cervical rib is bilateral, 33% in the right side and 36% in left side. The incidence of bilateralism is low in our study, in comparison to other studies.

The neurogenic TOS usually detected earlier than arterial counterpart, because of pain occurring early in the course of the disease. Usually, aTOS is recognized only after the occurrence of distal thromboembolism causing distal ischemic changes. Associated distal arterial lesion is found in 66% of cases. Thrombus is seen in 15 cases (50%), most commonly associated with aneurysml lesion of SCA. Once there is arterial damage in the form of intimal damage, post stenotic dilatation or aneurysm, there is a high chance of having thrombus and distal embolism.

The incidence of distal thromboembolism is more when there is an associated arterial dilatation or aneurysm, but minimal in cases where the artery is normal. The commonest distal site of occlusion is brachial artery (23 cases), followed by forearm arteries in 7 cases. As the distal arteries are involved, there are high chances of digital gangrene.

6.3. OPERATIVE DETAILS

The route of approach in all cases is supraclavicular. One patient, who had involvement of 1st part of SCA, needed lateral thoracotomy to take control of 1st part for arterial repair. Supraclavicular approach is selected for facilitating arterial reconstruction as well as decompression of the thoracic outlet by single approach. [53] The disadvantage of

supraclavicular approach is that it is not best suitable in removing the anterior part of 1st rib. As per our department protocol, we do not routinely remove the first rib. Combined supra and infra clavicular approach [54] can be used, in case there is a need to remove 1st rib also.

In all cases the bony component causing compression at thoracic outlet is removed. Cervical rib excision is done in 28 (93%) cases and removal of anomalous first rib in one case. There is no obvious bony component in 2 cases, of which one had MRI proven soft band compression.

Associated anterior scalenotomy is done in 19 cases. Usual removal of first rib is not done in our department. There are studies, comparing scalenectomy only to scalenectomy with first rib resection, and found no significant improvement statistically.

When there is no obvious arterial involvement, as in Scher I lesions, only decompression procedure is done. When there is only a simple dilatation of the artery, there is no need for arterial repair. Just decompression of the thoracic outlet is enough to cause subsequent shrinking of the dilated arterial segment. However, there is always a chance for distal embolisation from the thrombi evaluating from the dilated segment. So it is always our policy to open the arterial segment to see the intima, whenever there is distal pulse discrepancy or suspicion of distal embolisation.

Simple arteriotomy and direct closure is done in 5 cases, where there is no intimal disease. If thrombus is found, intimothrombectomy was done, to clear the source of distal emboli. When there is arterial dilatation/aneurysm, tailoring of the arterial wall is done. 4 cases need arterial repair, one with resection and anastomosis and three with interposition graft. The choice of graft is decided by the surgeon and availability of graft. Usually there is no need for any interposition graft, but when there is tension at the anastomotic site, either autogenous vein or synthetic graft should be used.

Whenever there is evidence of distal thromboembolism, distal embolectomy is done as an additional procedure. Transsubclavian route is preferred. But, if there is doubtful distal clearance, transbrachial embolectomy also done. 18 cases (60%) underwent distal brachial embolectomy procedure.

6.4. PROGNOSIS

17 patients have no peri-operative or post-operative complications. Out of 3 patients (10%), who had morbidity, 2 had intercostals drainage tube and 1 had surgical site hematoma.

After surgery, the functional outcome of the disease is decided by the frequency of previous thromboembolism to the distal vascular bed and the presence of collaterals. In this study, 5 patients have tissue loss. 1 patient(3%) have major amputation, but he presented with Rutherford class III ischemia on admission. other 4 patients who presented with gangrene of fingers, underwent finger disarticulation after surgery, once the lesions are demarcated.

During the 2 year follow up period, no patient developed neither new symptoms nor there any persistence of old symptoms.

SUMMARY

SUMMARY

This study, documents a prospective analysis of 30 patients who are admitted in our department, with symptoms suggestive of aTOS. The study group included representatives from age group 16 to 67 years, with maximum incidence in the 2nd and 3rd decade. Males outnumbered females by about 3:2 times. The observation of more males in our study does not agree with the previous studies. The incidence in females is one decade earlier than males and 75% of females are below the age of 30 years.

On the side of presentation, there is left side predominance in males and right side predominance in females, with overall left predominance. The left side prevalence is against the proven statistics, but may be insignificant in considering the small size of our study.

Claudication of the affected limb is the commonest (90%) presentation, followed by acute ischemic limb due to distal embolism (47%). Additional neurogenic pain is seen in 20% patients. The severity of symptoms depends on the severity of arterial lesion. Equal patient distribution is seen is all 3 stages of Scher classification and the arterial involvement is most likely in higher stage.

All patients have cervical X-ray, which picked up the bony compressive element. Cervical rib was diagnosed in 28 patients (93%) and anomalous first rib in one patient. In one case, MRI

was used to confirm the presence of soft tissue compression. Duplex scan helped in 70% cases to delineate the arterial involvement and CT angiogram done in 3 cases only.

All 30 patients underwent surgery via supraclavicular approach and all had decompression of the bony/soft tissue element. No arterial procedure is done in Scher I lesions. Endoaneurysmorraphy with thromboendarterectomy is done in 15 patients and 18 patients underwent distal thrombectomy. 4 patients have arterial repair done. 3 patients have peri-operative morbidity and 5 patients have amputation, only one major. With 2 year maximum follow up period, no patient has residual or recurrent symptoms.

CONCLUSIONS

8. CONCLUSIONS

Arterial complications due to compression at thoracic outlet are uncommon, comprising only less than one percent. But, it can result in significant morbidity and long term disability. Early recognition and surgical decompression provides favourable outcome in majority of patients.

Two unanticipated results in this study are (1) higher incidence in males and (2) left side cervical rib predominance. Arterial thoracic outlet syndrome is usually associated with bony component, and as cervical ribs are more common in females, the assumption is that females are more commonly associated with aTOS. This may be a wrong notion and in aTOS it may be that it is equal in both sexes. And also, this syndrome is the result of two factors added together: one is the anatomical narrowing and another is continuous trauma, causing changes in the muscle type. So, males being prone to repeated trauma, they are at higher risk in developing aTOS. Study at a larger scale is needed to confirm this.

Left sided predominance in this study cannot be considered significant, considering the size of the study.

In most patients, presence of cervical rib does not mean aTOS. In early stages of arterial compression, patient is usually asymptomatic, and the disease progresses silently. Only when, there is a distal embolism causing ischemic changes, this condition is diagnosed. If patients could be diagnosed before arterial changes occur, even at the stage of minimal post stenotic dilatation, just by decompressing thoracic outlet without any arterial repair, changes can be reversed. Mild symptoms, especially unilateral Reynaud syndrome needs further investigation to rule out thoracic outlet arterial compression.

Supraclavicular approach to tackle both bony component and arterial lesion is the best option in aTOS. Removal of the compressing bony component only without first rib removal is not affected the subjective and objective improvements in our patients. Resection of first rib is not necessary in our view. The results in our patients confirm the effectiveness of only removing the agent of compression.

The choice of arterial repair depends on the condition of the artery. No arterial intervention in simple dilatation and resection and anastomosis when there is aneurismal dilatation. This approach has minimal complications and maximum benefit. Distal embolectomy should be considered in all cases of acute limb ischemia, depending on the duration of occlusion and condition of the distal run-off vessels and collaterals.

In conclusion, this study confirms that when thromboembolic complications are present, surgery is indicated in all aTOS cases. However earlier diagnosis before thromboembolism should be the goal. We also conclude that supraclavicular approach and cervical rib excision without first rib excision is an effective procedure.

BIBLIOGRAPHY

1. Cooper A: On exostosis. In: Cooper AP, Travers B, ed. Surgical Essays, 3rd ed. 1821:128.

2. Coote H: Exostosis of the left transverse process of the seventh cervical vertebra, surrounded by blood vessels and nerves; successful removal. Lancet 1861; 1:360-361.

3. Hodgson: Diseases of Arteries and Veins. 1815.

4. Cooper AP, Travers B: Surgical Essay. 1818.

5. Benedik L: Raynaudscher symptomkomplex bei Halsrippe. Dtsche Z Nervenh 1924; 82:217.

6. Billington W: Excision of subclavian aneurysm associated with cervical rib. Br J surg 1924; 19:334.

7. Luke CJ, Fountain EM: Vasospasm and occlusive arterial changes in the fingers due to cervical rib. CMAJ 1950; 62:379.

8. Schein CJ, Haimovici H, Young H: Recent advances in surgery: arterial thrombosis associated with cervical ribs: surgical considerations. Report of a case and review of the literature. Surgery 1956; 40:428-443.

9.Halsted WH: An experimental study of circumscribed dilation of an artery immediately distal to a partially occluded band, and its bearing on the dilation of the subclavian artery observed in certain cases of cervical rib. J Exp Med 1916; 24:271-286.

10. Roach MR: Changes in arterial distensibility as a cause of poststenotic dilatation. Am J Cardiol 1963; 12:802-815.

11. Petronio R: Su un caso di thrombosi della subclavia in soggetto concosta cervicale. Ospedale Maggiore (Milano) 1952; 40:488.

12. Judy KL, Heymann RL: Vascular complications thoracic outlet syndrome. Am J Surg 1972; 123:521-531.

13. Malliet C, Fourneau I, Daenens K, et al: Endovascular stent-graft and first rib resection for thoracic outlet syndrome complicated by an aneurysm of the subclavian artery. Acta Chir Belg 2005; 105:194-197.

14. Meyer T, Merkel S, Lang W: Combined operative and endovascular treatment of a post-traumatic embolizing aneurysm of the subclavian artery. J Endovasc Surg 1998; 5:52-55.

15. Sitsen ME, Gwan HH, Blankensteijn JD: Deformation of self-expanding stent-grafts complicating endovascular peripheral aneurysm repair. J Endovasc Surg 1999; 6:288-292.

16. Martinez BD et al.: Computer-assisted instrumentation during endoscopic transaxillary first rib resection for thoracic outlet syndrome: a safe alternate approach, Vascular 13(6):327–335, 2005.

17. Machleder HI. Vascular disorders of the upper extremity. 3rd ed. Mt. Kisco, New York: Futura Press; 1999.

18. Todd TW. The relations of the thoracic operculum considered in reference to the anatomy of cervical ribs of surgical importance. J Anat 1911; 45:293.

19. Gruber W. Uber die Halsrippen des Menschen mit vergle-ichendanatomischen Bemerkunge. Mem Acad Imper Sci 1869; 7 (ser 13).

20. Gilliatt RW, Le Quesne PM, Logue V, Summer AJ. Wasting of the hand associated with a cervical rib or band. J Neurol Neurosurg Psychiatry 1970; 33:615.

21. Hamilton WJ, Boyd JD, Massman WJ. Human Embryology, 3rd edn. Cambridge, 1952:548.

22. Coote H. Exostosis of the left transverse process of the seventh cervical vertebra, surrounded by blood vessels and nerves: successful removal. Lancet 1861; 1:360.)

23. While JC, Poppel MH, Adams R. Congenital malformations of the first thoracic rib: a cause of brachial neuralgia which simulates the cervical rib syndrome. Surg Gynecol Obstet 1945; 81:643.

24. Green RM: Vascular manifestations of the thoracic outlet syndrome. Semin Vasc surg 1988; 11:67-76.

25. Casbas L, Chauffour X, Cau J, et al: Post-traumatic thoracic outlet syndromes. Ann Vasc Surg 2005; 19:25-28

26. Durham JR, Yao ST, Pearce WH, et al: Arterial injuries in the thoracic outlet syndrome. J Vasc Surg 1995; 21:57-70

27. Lee TS, Hines GL: Cerebral embolic stroke and arm ischemia in a teenager with arterial thoracic outlet syndrome: a case report. Vasc Endovascular Surg 2007; 41:254-257

28. Hugl B, Oldenburg A, Hakaim AG, Persellin ST: Unusual etiology of upper extremity ischemia in a scleroderma patient: thoracic outlet syndrome with arterial embolization. J Vasc Surg 2007; 45:1259-1261

29. Fields W, Lemak N, Ben-Menachem Y: Thoracic outlet syndrome: review and reference to stroke in a major league pitcher. AJNR Am J Neuroradiol 1986; 146:809-814

30. Symonds CP: Two cases of thrombosis of subclavian artery with contralateral hemiplegia of sudden onset, probably embolic. Brain 1927; 50:259-260

31. Naz I, Ziad S: Cerebral embolism: distal subclavian disease as a rare etiology. J Pak Med Assoc 2006; 56:186-188

32. Hugl B, Oldenburg A, Hakaim AG, Persellin ST: Unusual etiology of upper extremity ischemia in a scleroderma patient: thoracic outlet syndrome with arterial embolization. J Vasc Surg 2007; 45:1259-1261

33. Adson AW: Surgical treatment for symptoms produced by cervical ribs and the scalenus anticus muscle. Surg Gynecol Obstet 1947; 85:687-700

34. Roos DB, Owens JC: Thoracic outlet syndrome. Arch Surg 1966; 93:71-74

35. Charon JP, Milne W, Sheppard DG, Houston JG: Evaluation of MR angiographic technique in the assessment of thoracic outlet syndrome. Clin Radiol 2004; 59:588-595

36. Reeser JC: Diagnosis and management of vascular injuries of the shoulder girdle of the overhead athlete. Curr Sports Med Rep 2007; 6:322-327

37. Dobrin PB: Poststenotic dilatation. Surg Gynecol Obstet 1991; 172:503-508

38. Scher LA, Veith FJ, Haimovichi H, et al: Staging of arterial complications of cervical rib: guidelines for surgical management. Surgery 1984; 95:664-669

39. Thompson RW, Petrinec D: Surgical treatment of thoracic outlet compression syndromes: diagnostic considerations and transaxillary first rib resection. Ann Vasc Surg 1997; 11:315-323

40. Robicsek F, Eastman D: "Above-under" exposure of the first rib: a modified approach for the treatment of thoracic outlet syndrome. Ann Vasc Surg 1997; 11:304-306

41. Modrall JG, Joiner DR, Seidel SA, et al: Superficial femoral-popliteal vein as a conduit for brachiocephalic arterial reconstructions. Ann Vasc Surg 2002; 16:17-23

42. Valentine RJ, Wind GG. Anatomic Exposures in Vascular Surgery. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2003:130.

43. Malliet C, Fourneau I, Daenens K, et al: Endovascular stent-graft and first rib resection for thoracic outlet syndrome complicated by an aneurysm of the subclavian artery. Acta Chir Belg 2005; 105:194-197

44. Meyer T, Merkel S, Lang W: Combined operative and endovascular treatment of a post-traumatic embolizing aneurysm of the subclavian artery. J Endovasc Surg 1998; 5:52-55.

45. Gelabert HA, Machlader HI: Diagnosis and management of arterial compression at the thoracic outlet. Ann Vasc Surg 1997; 11:359-366.

46. Warrens A, Heaton JM: Thoracic outlet compression syndrome: the lack of reliability of its clinical assessment. Ann R Coll Surg Engl 1987; 69:203-204.

47. T.J. Fogarty, R.A. White (eds.), Peripheral Endovascular Interventions, 3rd edition, springer; 425 -430

48. Sanders RJ, Hammond SL. Complications and results of surgical treatment for thoracic outlet syndrome. Chest Surg Clin N Am 1999;9:803–20.

49. Kiessling K, Pilstrom L, Bylund Aet al. Enzyme activities and morphometry in skeletal muscle of middle aged men after training. Scand J Clin Lab Invest 1974; 33:63.

50. Lang J. Topographische Anatomie des Plexus brachialis und Thoracic- Outlet Syndrome. Berlin: Walter de Gruyter, 1985.

51. Firsov GI. Cervical ribs and their distinction from under-developed first ribs. Arkh Anat Gistol Embriol 1974; 67:101.

52.Green RM: Vascular manifestations of the thoracic outlet syndrome. Semin Vasc Surg 1988; 11:67-76.

53. Reilly LM, Stoney RJ: Supraclavicular approach for thoracic outlet decompression. J Vasc Surg 1988; 8:329-334.

54. Robicsek F, Eastman D: "Above-under" exposure of the first rib: a modified approach for the treatment of thoracic outlet syndrome. Ann Vasc Surg 1997; 11:304-306.

ANNEXURES

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI -3

Telephone No : 044 25305301
Fax : 044 25363970

CERTIFICATE OF APPROVAL

To
Dr. R. Chitra
PG in MCH Vascular Surgery
Madras Medical College, Chennai -3

Dear Dr. R. Chitra

The Institutional Ethics committee of Madras Medical College, reviewed and discussed your application for approval of the proposal entitled " Arterial Complications of the thoracic outlet syndrome " No.10032012.

The following members of Ethics Committee were present in the meeting held on 22.03.2012 conducted at Madras Medical College, Chennai -3.

1.	Prof. S.K. Rajan. MD	-- Chairperson
2	Prof. Pregna B. Dolia MD Vice Principal, Madras Medical College, Chennai -3 (Director , Institute of Biochemistry, MMC, Ch-3)	-- Member Secretary
3.	Prof. B. Kalaiselvi. MD Prof of Pharmacology ,MMC, Ch-3	-- Member
4.	Prof. C. Rajendiran. MD Director , Inst. Of Internal Medicine, MMC, Ch-3	-- Member
5.	Thiru. S. Govindsamy. BA BL	-- Lawyer
6.	Tmt. Arnold Soulina MA MSW	-- Social Scientist

We approve the proposal to be conducted in its presented form.

Sd/ Chairman & Other Members

The Institutional Ethics Committee expects to be informed about the progress of the study, and SAE occurring in the course of the study, any changes in the protocol and patients information / informed consent and asks to be provided a copy of the final report.

Member Secretary, Ethics Committee

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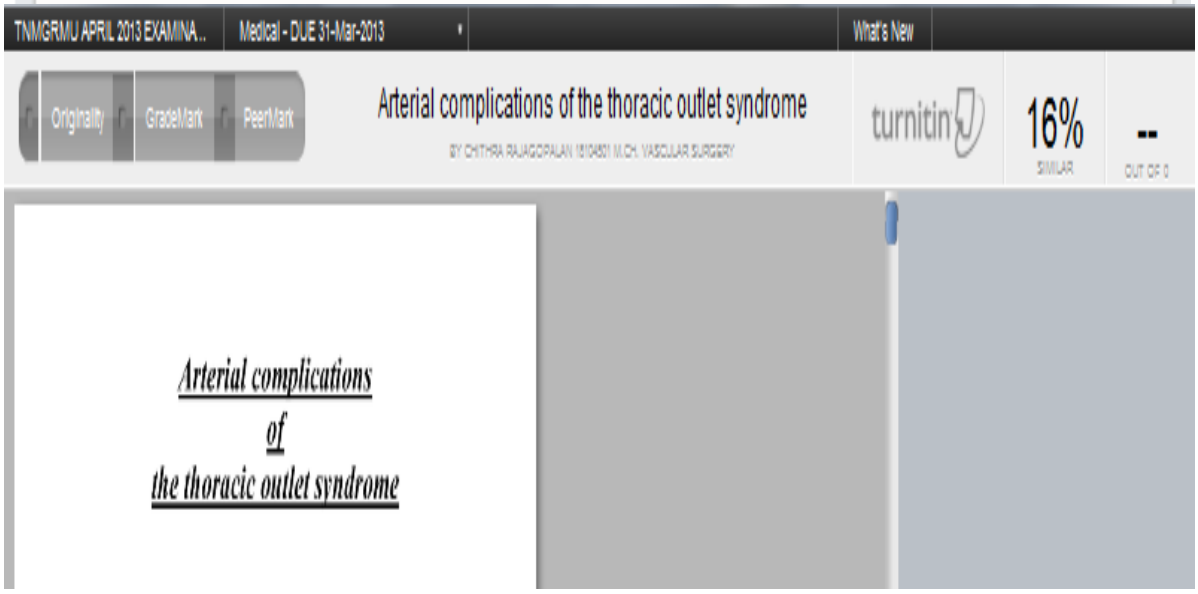
Submission time	22-Feb-2013 06:18PM
Total words	10463

First 100 words of your submission

Arterial complications of the thoracic outlet syndrome PART I – REVIEW OF LITERATURE 1.1. Introduction Thoracic outlet syndrome (TOS) describes a spectrum of symptoms and signs related to the passage of key anatomical structures through a narrow aperture on their way to the distal upper extremity. TOS results from compression of the neurovascular bundle in thoracic outlet area and the three components of the bundle in the thoracic outlet area are the brachial plexus, subclavian vein, and subclavian artery (SCA). Thus, there are three types of TOS, depending on which structure is compressed: neurogenic (nTOS), venous (vTOS), and arterial (aTOS). The commonest form of TOS is neurogenic type....



Annexure III: Patient Consent Form

DEPARTMENT OF VASCULAR SURGERY,

MADRAS MEDICAL COLLEGE, CHENNAI.

The patients in this study will be required to undergo physical examination, laboratory investigations and radiological investigations like Chest X-ray, duplex ultrasound and computed tomography.

AUTHORISATION:

Name of the patient: D.O.B:

1) I agree entirely voluntarily to take part in this study. I am ≥ 18 years of age.
2) I have been given full explanation of the purpose of the study and information regarding the procedures involved and what will be expected out of me.
3) I understand that I am entirely free to withdraw from the study at any time and this withdrawal will not affect my future treatment or medical management.
4) I understand that the information in my medical record is essential to evaluate the result of the study. I agree to the release of this information on the understanding that it will be treated confidentially.
5) I understand that I will not be referred to by any name in any report concerning the study. In turn I cannot restrict the use of the result which arises from this study.
6) I agree for the clinical photographs taken during the course of the study and agree for the use of it in the future.

Signature/ thumb impression of the patient Signature of the supervising Doctor

Date: Date:

Signature/ thumb impression of the witness:

Date:

Annexure IV: Information Sheet

We are conducting a study on “Arterial complications of the thoracic outlet syndrome” among the inpatients of ward 49, Department of Vascular surgery at Rajiv Gandhi Government General Hospital, Chennai .

The purpose of this study is to identify the patients presenting with arterial complications of Thracic Outlet Syndrome and assess their limb salvage rates.

The privacy of the patients in the research will be maintained throughout the study. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

Taking part in this study is voluntary. You are free to decide whether to participate in this study or to withdraw at any time; your decision will not result in any loss of benefits to which you are otherwise entitled.

The results of the special study may be intimated to you at the end of the study period or during the study if anything is found abnormal which may aid in the management or treatment.

Signature of investigator Signature of participant

Date: Date:

Annexure V: MASTER CHART

ADM	SYMP	side	site of lesion	Scher	CXR	CTA	Art lesion	thromb	comp agent	surg tech	decomp	result
1	2,3	2	1	2	2	2	1	2	1, 4	2	3	1
2	2,3,4	1	2	3	3	2	2	2	2	5	2	1
2	2,3,4	2	2	3	3	2	1	1	1	3	2	1
2	1,2,3,4	2	2	3	2	2	2	1	1	3	2	1
1	2,3	1	4	1	1	2	4	2	1	4	1	1
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2	2,3,4,5	1	2	3	1	2	1	2	1	3	2	1
1	2,3	1	3	3	3	1	1	1	2	3	1	1
2	2,3	1	2	3	1	2	2	1	2	5	2	1
1	2,3,5	2	1	1	2	2	4	2	2	4	1	1
1	5	2	4	1	2	2	4	2	1	4	1	1
1	5	2	4	1	2	2	4	2	1	4	1	1
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2	2,3,4	1	2	3	3	2	2	1	2	3	2	3
1	2,3,5	2	1	1	1	2	1	2	4	1	3	1
1	2,3	1	4	1	1	2	4	2	2	4	2	1
1	2,3	2	4	1	2	2		2	1	4	1	1

Annexure VI: Key to Master Chart

- **Sex**
  - 1 = Male, 2 = Female
- **Admission**
  - 1 = Elective, 2= Emergency
- **Symptoms**

  1=Vasomotor 2=Claudication 3=Digital gangrene
  4=Acute limb ischemia 5=Neurological
- **Side of Symptoms**
  - 1 = Right , 2 = Left
- **Site of distal arterial lesions**

  1 = Forearm vessels, 2 = Brachial artery, 3 = Axillary artery, 4 = Nil
- **Schers' stage on presentation**
  - 1 = stage I, 2 = stage II, 3 = stage III
- **Side of lesion in X-ray**
  - 1 = Right, 2 = Left, 3 = bilateral
- **Role of CT Angiogram**
  - 1 = Taken, 2 = not taken
- **Arterial lesion**
  - 1 = Dilatation, 2 = aneurysm, 3 = No lesion
- **Presence of thrombosis**
  - 1 = Yes, 2 = No
- **Nature of compressing agents**
  - 1 = incomplete cervical rib, 2 = Complete cervical rib, 3 = First Rib, 4 = soft tissue
- **Nature of arterial repair**
  - 1 = Endarterectomy, 2 = Endarterectomy + Embolectomy. 3 = 2 + Distal thrombectomy, 4 = Vascular repair, 5 = Nil
- **Nature of decompression**
  - 1 =Cervical rib excision, 2 = 1 + soft tissue excision, 3 = 1 + Scalenectomy, 4 = first rib excision
- **Out come**
  - 1 = Improvement, 2 = No improvement, 3 = Same
- **Pressure improvement postoperatively**
  - 1 = Improvement, 2 = Deterioration, 3 = Same
- **Reappearance of pulse postoperatively**
  - 1 = Reappeared, 2 = Same